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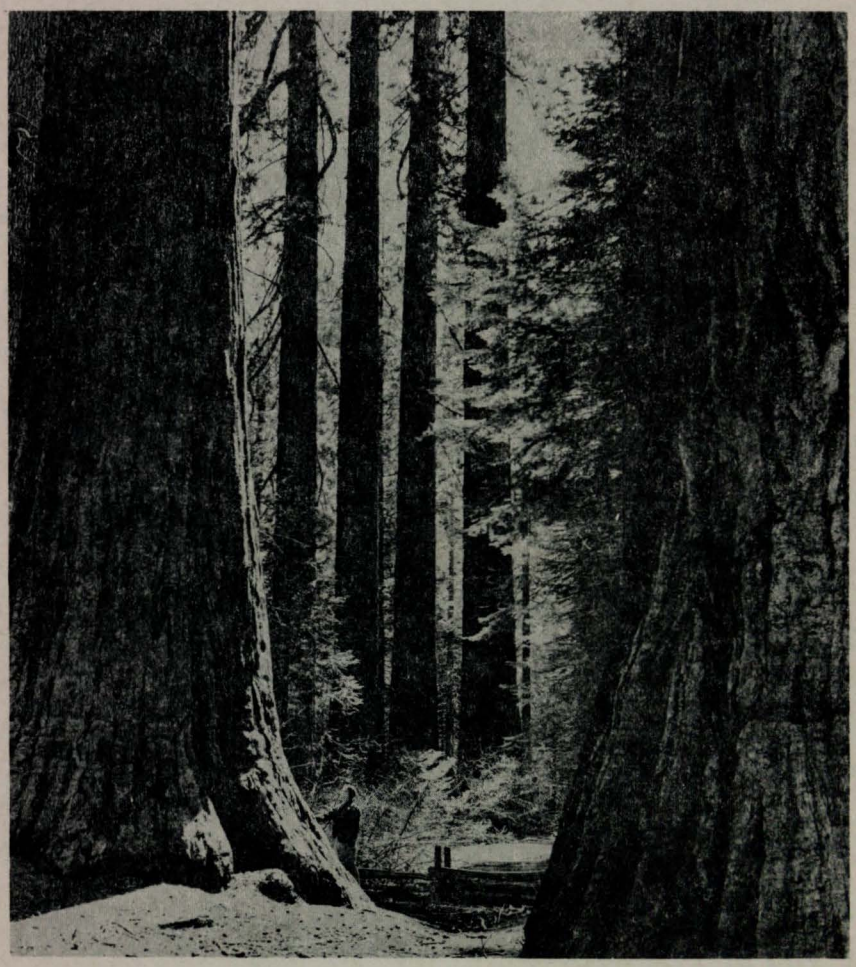
SILVICAL CHARACTERISTICS OF GIANT SEQUOIA

Gilbert H. Schubert



PACIFIC SOUTHWEST
FOREST AND RANGE
EXPERIMENT STATION
BERKELEY, CALIFORNIA

Technical Paper 20
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by N. M. Beetham

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Preface

The U.S. Forest Service is assembling information on the silvical characteristics of important forest trees of the United States. Much material of value in silviculture and research is widely scattered and difficult to locate. This report presents, in preliminary form, the information that has been collected for one species of trees. Similar reports are being prepared or revised for other species at the Pacific Southwest Forest and Range Experiment Station and at other Forest Experiment Stations. Readers are encouraged to notify the authors of any omissions, errors, or new information.

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By

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Revised by

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CONTENTS PAGE

Habitat Conditions. 1
Climatic 1
Edaphic. 1
Physiographic. 3
Biotic 3
Life History. 4
Seeding Habits 4
Flowering and Fruiting. 4
Seed Production 4
Seed Dissemination. 5
Vegetative Reproduction. 5
Seedling Development 6
Establishment 6
Early Growth. 9
Seasonal Growth 10
Sapling Stage to Maturity. 10
Growth and Yield. 10
Reaction to Competition 11
Principal Enemies 12
Special Features. 13
Races and Hybrids 13
Literature Cited. 14

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U.S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE
PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION
Berkeley, California

SILVICAL CHARACTERISTICS OF GIANT SEQUOIA

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Giant sequoia (Sequoia gigantea (Lindl.) Decne.) is the world's largest tree in terms of volume (27).[1/] Within its natural range it grows in more or less isolated groves on the western slopes of the Sierra Nevada in central California. These groves, variously listed at 25 to 72 by different authorities (7, 9, 12, 13, 16, 17, 23, 27, 30, 32), lie in a narrow belt about 260 miles long (fig. 1). The six trees in the northernmost group stand along the Middle Fork of the American River in Placer County. The southernmost grove with 100 trees is near Deer Creek in Tulare County.

HABITAT CONDITIONS

CLIMATIC

Giant sequoia grows in a colder and drier climate than does the redwood (Sequoia sempervirens (D. Don) Endl.) (30, 32). Annual precipitation varies with altitude and from year to year. It ranges from 18 inches to more than 60 inches (27, 30, 32). The best stands develop in protected locations having an average annual precipitation of 45 to 60 inches (27).

Most precipitation occurs as snow during September through May. Summer storms are infrequent. Snow falls throughout the range of giant sequoia and reaches depths of 10 feet or more. During the winter of 1905-6, snow in the Giant Forest, Sequoia National Park, lay 29 feet deep; in protected spots, snow still stood 12 feet deep by midsummer (12).

The temperature occasionally drops to -12°F. and seldom exceeds 100°F. The lowest temperature recorded in the Giant Forest, one of the largest and best developed groves, was -5°F. and the highest was 94°F. The average growing season lasts 124 days, from June 2 to October 4 (31).

EDAPHIC

Giant sequoia grows on a wide variety of soils from shallow rocky to deep sandy loams (32). Although it develops on shallow, moderately dry soils, the tree grows best on moist, deep, well drained soils slightly to moderately acid in reaction. The best growth of seedlings has been observed in soils of pH 6; poorer growth was found at pH 5 and 7 (4). Seedlings planted in wet soil do not survive because of low aeration.

1/ Underlined numbers in parentheses refer to literature cited.

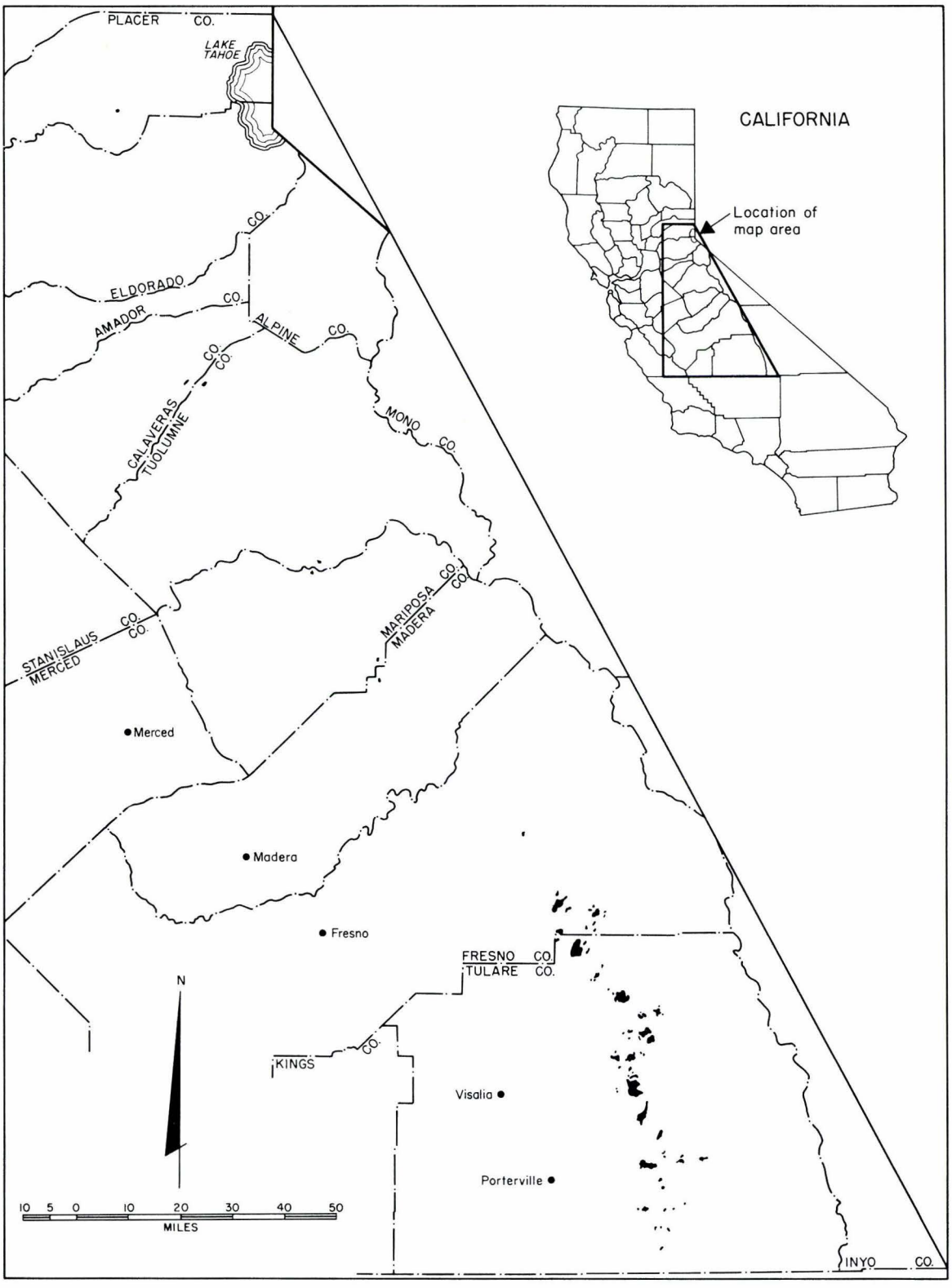

Figure 1.--The natural range of giant sequoia. (Adapted from California Department of Natural Resources (7).)

The soils of the sequoia groves are generally developed from granitic, dioritic, or andesitic rocks. The most common soil series are Holland, Olympic, and Sierra.

PHYSIOGRAPHIC

Most groves grow at elevations between 4,500 and 7,500 feet (7, 27). Some occur as low as 3,000 feet and a few at 8,900 feet. At the northern part of their range the trees grow at 4,500 to 5,500 feet; in the central part, at 5,400 to 7,000 feet; and at the southern end, at 6,000 to 8,000 feet.

Giant sequoia grows on slopes of all apsects. The groves are generally found in canyons having adequate soil moisture. They also occur on or near the tops of high exposed ridges where underground water is available (7, 13, 32).

BIOTIC

Giant sequoias grow in small groves within the ponderosa pine-sugar pine-fir type (29). They never make up pure stands, except over small areas.

Trees commonly associated with giant sequoia include:

California black oak (Quercus kelloggii Newb.)
Incense-cedar (Libocedrus decurrens Torr.)
Ponderosa pine (Pinus ponderosa Laws.)
Sugar pine (Pinus lambertiana Dougl.)
White fir (Abies concolor (Gord. & Glend.) Lindl.)

Other trees found growing with giant sequoia include:

Bigleaf maple (Acer macrophylum Pursh)
Bitter cherry (Prunus emarginata Dougl.)
California red fir (A. magnifica A. Murr.)
Canyon live oak (Q. chrysolepis Liebm.)
Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco)
Jeffrey pine (Pinus jeffreyi Grev. & Balf.)
Pacific dogwood (Cornus nuttallii Audubon)
White alder (Alnus rhombifolia Nutt.)

Common brush species occurring with giant sequoia include:

Bearmat (Chamaebatia foliolosa Benth.)
Bush chinkapin (Castanopsis sempervirens Dudley)
Deerbrush (Ceanothus integerrimus H. & A.)
Greenleaf manzanita (Arctostaphylos patula Green)
Littleleaf ceanothus (C. parvifolius Trel.)
Mountain whitethorn (C. cordulatus Kell.)
Scouler willow (Salix scouleriana Barr.)
Snowbrush (C. velutinus Dougl.)
Western azalea (Rhododendron occidentale Gray)

LIFE HISTORY

SEEDING HABITS

Flowering and Fruiting

Male and female flower buds form on the same tree during late summer, but may not be noticed until the following spring when they begin to swell and open (5). The ovule-bearing strobili originate on the larger twigs near the branch tips but rarely on the leaders. The pollen-bearing strobili form on the smaller twigs.

Pollination usually occurs between the middle of April and the first of May when the conelets are only two or three times as large in diameter as the twigs bearing them (5). The female conelets are about one-third mature size by the end of the first growing season. When they mature at the end of the second growing season, they are 2 to 3.5 inches long (6). Some of the southernmost groves, however, have individual trees that produce larger cones (4).

Seed Production

In one study the number of seeds per cone varied from 97 to 306, and averaged about 230. The greatest number of seeds found in a single cone was 329 (12).

Giant sequoia usually begin to produce large numbers of cones only after they are 150 to 200 years old (13). Cones have been observed on 18- to 24-year-old saplings, but they usually contain only infertile seeds (13, 27, 32). Heavy cone crops with viable seeds have been found on some trees 50 to 75 years old (20).

Seeds stored in cones on the tree and extracted seeds in cold storage retain their viability for long periods (5, 12, 26). Two seed lots held in cold storage at 41°F. (5°C.) still had a viability of 41 to 43 percent after 16 and 17 years (26).

Cones are generally produced each year, the largest trees bearing enormous quantities of them (32). The immense size of the trees and the relatively small size of the cones make it impossible to count accurately the number produced. Attempts at systematic counting have shown that a mature tree averages about 2,000 cones per year (4).

Not all newly grown cones survive to maturity. In one instance, all 1-year-old cones were reported frozen during the summer of 1906 (12). The 2-year-old cones on the same trees were not affected. Freezing may have destroyed some immature cones during other years, but no other report of such injury could be found.

Squirrels, particularly the Douglas squirrel (Tamiasciurus douglasii Backman), cut and cache vast numbers of mature cones for their winter food supply (12). These cone caches provide a convenient source for seed collectors.

Rodents outside the giant sequoia groves show little interest in the cones, especially if they can find other food. A series of preference experiments held at the Stanislaus Experimental Forest in Tuolumne County, California, tested 14 types of local seeds, fruits, and cones. Giant sequoia seeds and cones ranked tenth in order of preference (4). The rodents favored the larger pine seeds and acorns over the small giant sequoia seeds. They least preferred the resinous seeds of fir and incense-cedar and the cones of juniper.

Cones buried by rodents have doubtful value for establishing giant sequoias (4). Some seedlings do develop from seeds accidentally sown when rodents store cones. Seedlings do not grow from cached cones.

No seed or cone insects or diseases of economic importance have been reported for giant sequoia.

Seed Dissemination

In contrast with the habit of most conifers, giant sequoia seeds are not usually released the first year after the cones mature (5, 12). Cones may retain viable seeds for more than 14 years. One cone from a branch broken off a large tree during a wind storm was 19 years old and still held 137 seeds. This amount is more than half the average number of seeds normally found in mature cones.

Giant sequoia seeds are light and may be blown great distances by air currents. The number of seeds varies from 54,000 to 132,000 per pound; the average is 91,000 (22, 32). The exact distance that wind will carry these light seeds is not known; it may be several hundred yards (13). In one instance, wind carried them 580 feet (12). In the absence of turbulence, the seeds fall at a rate of about 4 feet per second (4).

Peduncles of cones produce annual rings (5). Cones borne on peduncles having only two growth rings are immature; those with peduncles having three or more rings are mature. Annual rings continue to form on peduncles bearing cones that have not shed all their seeds. Therefore, these annual rings can be counted to determine the age of cones. Cones which open and release their seeds die and turn brown, and their peduncles stop forming annual rings.

VEGETATIVE REPRODUCTION

Giant sequoia does not produce sprouts from roots or stumps as is common in redwood. But tall broken stubs and crowns sprout vigorously (30) and form new tops if enough live foliage remains below the break.

SEEDLING DEVELOPMENT

Establishment

Each giant sequoia in its lifetime potentially can produce 60 million offspring. But actual field counts show that few mature trees have produced more than three or four successful offspring. Two main reasons account for this poor establishment: dense shade and an inadequate moisture supply in the surface litter (4).

Adequate soil moisture is more critical than light for seedling establishment during the first few years. Young reproduction is generally found only in openings where root competition for moisture has been reduced (20, 21). Small openings are preferable to large ones, mainly because of the lower evaporation rate of soil moisture and of the partial shade in the more protected areas. However, good reproduction has filled in some large areas when logging was followed by a good seed year and favorable climatic conditions. It is important to realize that the litter which hinders seed germination is beneficial to seedling survival.

The largest giant sequoia seeds germinate two to three times better than small seeds and up to 15 percent better than seed of mixed sizes (4). For optimum germination, giant sequoia seeds need moist soil and temperatures between 35°F. and 80°F. Seed germination in the natural range of the species usually begins in February or March. The high soil temperatures in exposed areas do not favor seed germination in summer. Salt solutions of over 0.2 percent delay germination (4). Soil acidity has little influence on germination, but seedlings develop abnormally in soils at pH 5 or below. Seeds will not germinate in standing water.

Seeds germinate best on exposed mineral soil and in loose ashes on a freshly burned area (27, 32, 33). In the central and southern groves reproduction is abundant only where the soil has been disturbed after logging, fire, erosion, windthrow, or road construction (fig. 2). Very few seedlings are found in the northern groves where the litter is deep and dry.

Giant sequoia produces seedlings that cannot emerge to the surface if they are buried in more than 0.9 inch in the soil (4). The surface soil must remain moist throughout the early germination and seedling stages. Such strict conditions govern seed germination and seedling establishment that they occur infrequently in nature. Often giant sequoia reproduction appears to be even aged. This suggests that the necessary conditions for reproduction occurred simultaneously and infrequently.

Giant sequoia litter resists wetting. Burning the litter increases its water-holding capacity two or three times and reduces the depth of litter which seeds must penetrate for moisture (4). In heavy litter, moisture drains to the deeper levels, leaving the surface dry soon after a storm. The dry litter surface is not suitable for giant sequoia seed germination, and the small seeds are too light to penetrate the litter to more moist areas.

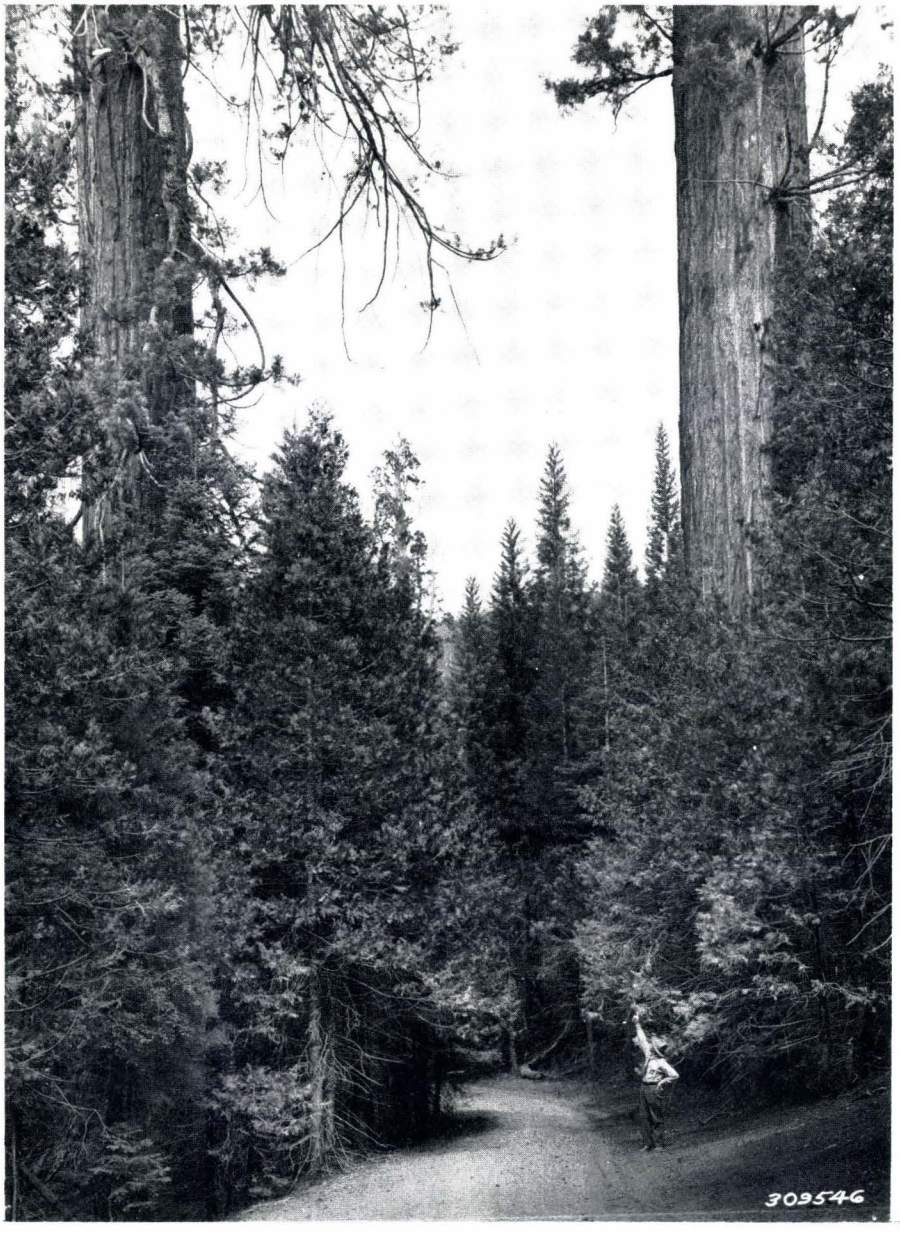

Figure 2.--Dense giant sequoia reproduction along road.

In some undisturbed groves, natural reproduction may be seen in openings on hillsides. Microerosion on hillsides tends to move the litter downslope and pushes the small seeds into the moister zones of the litter, resulting in excellent giant sequoia reproduction (4).

Periodic fires probably helped perpetuate giant sequoia groves by removing litter and making possible seed germination. Old stumps and trees display many fire scars of various ages. Fires must have occurred at infrequent intervals to allow the young growth to reach a fire resistant

age of 150 years or more. The occurrence of young trees of uniform ages suggests that reproduction may be fire dependent. But reproduction may also depend upon the absence of fire after giant sequoia becomes established.

Young trees rarely become established in dense grass cover, probably because water becomes depleted from the surface soil early in the season (4).

During the first stages of seedling establishment, light shade will reduce injury and death from heat canker, especially when the seedlings grow in open areas on light-colored soils (4). Litter added to the soil cuts down the heat reradiated from the soil to air. It appears to be more effective than lathe or similar shades in reducing soil temperature. Litter lessens soil moisture losses and damage from warmth-loving soil fungi which injure roots. Sclerotium batalicola Taub. is a common high-temperature soil fungus which will kill giant sequoia seedlings in exposed areas with high soil temperature. Damage from this fungus can be reduced by applying methyl bromine on the soil.[2/]

Giant sequoia seedlings grown in full sunlight on litter-protected soil produced 86 percent more height growth than those grown in 75 percent of full sunlight (4). Seedlings grown in 50 and 25 percent of full sunlight had low growth rates. Where only 2 percent of full sunlight reached the seedlings, the growth form was altered, resulting in soft, lax branches, in light yellow-green foliage, in weak stems, and in expanded needles. These seedlings quickly died when brought into full sunlight. Survival under dense shade was 80 percent and growth 2.6 percent that of the control group. The results in this study do not agree with those from earlier investigations (28).

Seedlings exposed to winter light intensities in the central Sierra Nevada turn brownish-purple and appear almost dead. If these seedlings are kept in the shade in winter, no browning occurs and the young trees remain a rich greenish-green-yellow.[3/] A few physiological ecotypes which stay green during winter when exposed to full sunlight have been found (4).

During the first few months after germination, many seedlings are destroyed by such birds as sparrows (Zonotrichia spp.) and California purple finches (Carpodacus purpureus californicus); by such animals as gophers (Thomomys spp.), ground squirrels (Citellus spp.), and chipmunks (Eutamias spp.); and by cutworms (Noctuidae spp.).

Many seedlings die in areas where the soil is too wet or too dry. When the soil moisture at 6 inches' depth exceeds 18 to 20 percent or falls

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2/ Bega, R. V. Personal communication. U.S. Forest Serv., Pacific Southwest Forest and Range Expt. Sta., Berkeley, California. 1961.

3/ Color designations from the Munsell color chart.

below 5.5 percent in sandy loam, conditions do not suit seedling survival. Short periods of excessive soil moisture do little damage, but aeration becomes inadequate during long periods of floods. Severe root competition for the limited soil moisture supply reduces the chance of seedling establishment in old stands (20).

Once giant sequoia seedlings become established, they have a good chance of surviving competitive species. Well established seedlings are able to overtop and kill most brush species. The percent composition of young reproduction in existing groves shows the following (4):

Species	Percent composition
White fir	60.2
Incense-cedar	24.1
Sugar pine	9.3
Ponderosa pine	3.5
Sequoia	1.0
Others	1.9

Early Growth

Height growth of sequoia seedlings begins slowly during the first year, but increases rapidly after the second or third year (27). Growth is rapid once the roots reach continually moist soil (4). One-year seedlings are from 1 to 3 inches tall. By the end of the second year, they are 3 to 6 inches, and after three growing seasons, 6 to 12 inches tall. Sterilization of the soil with methyl bromine has helped develop seedlings 6 inches tall in 4 to 6 months.[4/] Trees 35 years old average between 45 and 87 feet tall depending on the site quality and competition with other trees (20). With an even start, giant sequoias can outgrow any associated species (4, 20).

Exact root growth measurements have not been reported, but root elongation is probably rapid. During the first few years, the main root system consists of a taproot with few laterals (23). This two-storied root system is well adapted to the dry summer climate of California and may explain the superior survival (compared with white fir and incense-cedar) after transplanting. A study showed only 26 percent of the sequoia seedlings survived after root pruning because of infection from root fungi and an inadequate root system (4).

After 6 to 8 years, lateral root growth predominates, and elongation of the taproot practically stops. This may be due to poor aeration in the deep soil (4). Later in the life of the giant sequoia, the lateral root system may spread over an area of 2 to 3 acres but none of the roots

4/ Bega, R. V. Personal communication. U.S. Forest Serv., Pacific Southwest Forest and Range Expt. Sta., Berkeley, Calif. 1961.

more than 6 to 8 feet deep (12, 23). This widespread root system provides excellent support for the tree throughout its lifespan. Giant sequoia roots commonly intergraft.

Seasonal Growth

Data on beginning dates or duration of seasonal radial or height growth of giant sequoia have not been published.

SAPLING STAGE TO MATURITY

Growth and Yield

Giant sequoia is not the tallest species and occasional individuals of other species may surpass it in basal circumference, but it is the most massive tree in the world (27). The greatest volume of a single tree was estimated at 600,120 board feet. Many trees have a gross volume of more than 500,000 board feet (9).

The 272-foot General Sherman tree in the Giant Forest has the greatest circumference of the measured giant sequoias. Its basal circumference is 101.6 feet (2). The tallest giant sequoia (the California tree in the General Grant Grove, Kings Canyon National Park) towers 310 feet (27). Trees 275 feet tall with an average basal diameter of 20 feet are common in the southern groves, which have the best stands (25, 32).

Giant sequoias are long-lived. Trees in many groves range from 2,000 to 3,000 years old, and a few are known to exceed 3,000 years (27, 32). The maximum age has been reported to be over 4,000 years (32), but no authentic records are available to support this claim. The actual age of the oldest giant sequoia is a subject of much speculation. Ring counts on felled trees indicate ages up to 3,200 years (27). Huge old trees, too large to be cut in earlier years and now standing protected, may be even older.

Giant sequoias grow rapidly during their youth, but slow down considerably in old age. Trees under 75 years old increase in diameter at an average rate of 1 inch every 3 to 5 years, but ancient over-mature trees may require more than 20 years to grow 1 inch in diameter (10).

Giant sequoias less than 100 years old retain most of their branches. In contrast, trunks of mature trees are generally free of branches up to a height of 100 to 150 feet.

Most giant sequoia groves stand on public lands withdrawn from cutting; only 12 percent of the total acreage remains in private ownership (7). Very few trees are being cut. In 1952 about 2 million board feet were harvested (8). This small-volume cut is chiefly due to the strong public desire to preserve old-growth trees. The amount cut in the future will probably continue to be small because most "specimen" or "museum" trees are in virgin stands that are 92 percent publicly owned (7).

Although giant sequoias are prized chiefly for their esthetic value, some stands could be placed under management for their timber products. In the northern part of the range, too few trees grow to have economic importance. But in the southern part, trees thrive in greater numbers, and the areas are better adapted to silvicultural treatments.

Mixed forests having giant sequoia as an important component could be managed to increase the quality and quantity of this species. About 34 percent of giant sequoia sites have been cut over and need silvicultural treatment. Some areas are poorly stocked or nonstocked and should be brought up to acceptable stocking standards by actual planting or acceptable site preparation measures to encourage natural regeneration. Such measures include creating small openings in the canopy by thinning out competing species of poor quality so more light can reach the forest floor. As fire retardants are perfected, they may be used around the bases of mature trees to prevent damage from control burns aimed at removing litter and debris.

Building bulldozer trails to remove litter and expose mineral soil may damage the esthetic appeal of the groves for a time, but will encourage the perpetuation of giant sequoias. Other areas have overdense thickets which should be thinned to prevent further stagnation and to increase the growth rate of the trees. Thinning would allow more room and light for giant sequoia seedlings and result in better forests. Still other areas require stand improvement measures to release potential crop trees from competition and to increase the proportion of giant sequoias in the final stands. In young stands, dominant large saplings and small poles would require pruning to produce clear lumber in rotations of less than 150 years.

A recent study of 52 giant sequoia groves showed that establishment of reproduction may depend upon land use (4). In groves subjected to heavy tourist traffic, only 1.7 young giant sequoias were present to replace each mature tree. In groves seldom visited by man, 3.0 young giant sequoias were present to replace mature individuals. Those groves which had been logged showed 7.3 young giant sequoias for each stump.

Periodic annual growth rates of giant sequoia have not been determined. However, rotation ages for second-growth stands will probably be based mainly on the size of the trees that can be harvested without serious loss from breakage. Generally, breakage, which runs from 45 to 50 percent in old trees, is not a serious factor in young trees.

Reaction to Competition

A study was recently made of the capacity of giant sequoias to develop seedlings and grow in close competition with white fir and incense-cedar seedlings. For best development, giant sequoias require protection of the soil by litter (4). They also need full overhead light (30, 32). Although individual trees may survive for many years in a retarded state, giant sequoia cannot mature under a closed canopy. Firs are better adapted

to shade, but do not withstand drought as well as the young giant sequoias. Incense-cedar can withstand moderate shade and as much drought as the giant sequoias (4).

Giant sequoias can endure more shade during youth than in old age (13, 32). In dense thickets growth is poor. When released, the spindling trees recover slowly. After the crown has filled out, growth becomes rapid.

Principal Enemies

Recent research supports previous studies indicating that giant sequoia has few important natural enemies other than fire and undermining by water (4, 15, 32.). Ground fires are especially destructive during the seedling and sapling stages (27, 32). Most trees larger than 10 feet in diameter have fire scars (10). Mature trees, protected by bark up to 2 feet thick, can survive repeated fires without serious loss (27). The shredded bark which gathers at the base may burn for weeks and produce heat intense enough to burn away the bark on one side (24). Repeated hot fires may hollow out large trees, especially on the uphill side where debris collects. Other species without shredded bark serving as fuel may be damaged less than the giant sequoias by light ground fires. Few old trees have been destroyed by fire alone. But some have been windthrown where roots have been destroyed by fire or road construction, or exposed by erosion after fires.

Soil compaction by the thousands of tourists who visit the groves each year has seriously reduced the vigor of the giant sequoias (19). This trampling around the tree base has destroyed many feeder roots necessary to supply the vast quantities of water required by the trees, reduced the water-holding capacity of the soil around the trees, and lowered the amount of water penetrating into the soil.

Occasionally, mature trees have been known to topple over on a calm day. This has been attributed to an imbalance of the crown. According to one theory, branches become heaviest on the side receiving the most light and produce imbalance (14). The true cause of the downfall is not known (1).

From time to time, lightning has damaged giant sequoias. Long periods of freezing weather may kill young trees.

Once established, giant sequoia is known for its resistance to insect and disease attacks (10, 27, 32). None of the insects reported found on giant sequoia has caused the death of a single tree (18). An unidentified brown heart rot caused some decay in large trees where heartwood had been exposed, but no trees have been killed by this disease (32). Although sapwood rots rapidly, old trees that fell centuries ago show little evidence of decay in the heartwood (27).

SPECIAL FEATURES

A high content of phlobatannin in the wood, bark, and cones of giant sequoia protects it against attacks by insects and diseases from seed formation to maturity (1).

The cones contain a highly colored water-soluble pigment (73 percent tannin, 3 percent organic matter, 1.5 percent ash, and 22 percent water) which has been reported (12) to (a) protect cones from fungus, (b) increase the germinative capacity of the seeds, (c) increase the retention of viability of the seeds, (d) increase the vigor of the seedlings, and (e) reduce the susceptibility of seedlings to insect and disease attacks.

Results from recent research have not shown that seeds germinate better after being treated with various concentrations of cone extract (4), but high concentrations of the pigment slow germination and may produce unfavorable osmotic effects. No indication was found that treated seeds produced more vigorous seedlings than seeds from recently matured cones that had little exposure to pigment.

RACES AND HYBRIDS

Giant sequoia has no known hybrids. Recognized varieties (3, 11) include:

Sequoia gigantea var. *argentea* Hort. (shoots and leaves silver and variegated).

Sequoia gigantea var. *aurea* Nicholson (shoots and leaves yellow).

Sequoia gigantea var. *glauca* Otto (leaves glaucous).

Sequoia gigantea var. *pendula* (Carriere) M. L. Green (main branches almost parallel with the trunk).

Sequoia gigantea var. *pygmaea* Hort. (dwarf, bushy habit).

LITERATURE CITED

(1) Anonymous.
1937. All about the sequoias, Dr. Horn's Quicky. 1:1-24.

(2) American Forestry Association.
1956. These are the champs. American Forests 62(4):33-40, illus.

(3) American Joint Committee on Horticultural Nomenclature.
1942. Standardized plant names. Ed. 2, 675 pp. Harrisburg, Pa.

(4) Beetham, Nellie M.
1961. The ecology of the seedling stage of Sequoia gigantea. (Unpublished doctor's dissertation. Copy on file Dept. of Botany, Duke University, Durham, N. C.)

(5) Bucholz, J. T.
1938. Cone formation in Sequoia gigantea. I. The relation of stem size and tissue development to cone production. II. The history of the seed cone. Amer. Jour. Bot. 25:296-305, illus.

(6) _____.
1939. The morphology and embryogeny of Sequoia gigantea. Amer. Jour. Bot. 26:93-101, illus.

(7) California Department of Natural Resources.
1952. The status of Sequoia gigantea in the Sierra Nevada. Report to the California legislature. 75 pp., illus. Sacramento.

(8) California Forest and Range Experiment Station.
1954. Forest statistics of California. Forest Survey Release 25. 6 pp., illus.

(9) Collingwood, G. H., and Brush, Warren D.
1955. Knowing your trees. 328 pp., illus. Washington, D. C.

(10) Cook, Lawrence F.
1942. Giant sequoia of California. 28 pp., illus. Washington, D. C.

(11) Dallimore, William, and Jackson, A. Bruce.
1948. A handbook of Coniferae. Ed. 3, 682 pp., illus. London.

(12) Fry, Walter, and White, John R.
1938. Big trees. 126 pp., illus. Palo Alto, Calif.

(13) Green, George Rex.
1933. Trees in North America (exclusive of Mexico). Vol. 1, The conifers. 186 pp., illus. Ann Arbor.

(14) Hall, William L., and Maxwell, Hu.
1911. Uses of commercial woods of the United States. I. Cedars, cypresses, and sequoias. U.S. Dept. Agr. Forest Serv. Bul. 95, 62 pp.

(15) Harlow, William M., and Harrar, Ellsworth S.
1950. Textbook of dendrology. Ed. 3, 555 pp., illus. New York, London, and Toronto.

(16) Jepson, Willis Linn.
1910. The silva of California. Vol. 2. 480 pp., illus. Berkeley.

(17) _____.
1923. The trees of California. Ed. 2, 240 pp., illus. Berkeley.

(18) Keen, F. P.
1952. Insect enemies of western forests. 280 pp., illus. Washington, D. C.

(19) Meinecke, E. P.
1928. Tree giants in the Sequoia Groves are menaced by tourists. Agr. Yearbook 1927. 1,234 pp., illus.

(20) Metcalf, Woodbridge.
1948. Youthful years of the bigtree. Pacific Discovery 1(3): 4-10, illus.

(21) _____.
1949. Timber growth studies; tree growth in Whitaker's Forest, Tulare County, during 33-year period; 1915-1948. Calif. Agr. 3(8):7, 14, illus.

(22) Mirov, N. T.
1940. Additional data on collecting and propagating the seeds of California wild plants. U.S. Forest Serv. Calif. Forest and Range Expt. Sta. Res. Note 21. 17 pp.

(23) Peattie, Donald Culross.
1953. A natural history of western trees. 751 pp., illus. Boston.

(24) Presnall, C.
1933. Fire studies in the Mariposa Grove. Yosemite Nature Notes 12:23-24, No. 3.

(25) Sargent, Charles Sprague.
1922. Manual of the trees of North America (exclusive of Mexico). Ed. 2, 910 pp., illus. Boston.

(26) Schubert, G. H.
1952. Germination of various coniferous seeds after cold storage. U.S. Forest Serv. Calif. Forest and Range Expt. Sta. Res. Note 83. 7 pp.

(27) Shirley, James C.
1947. The redwoods of coast and Sierra. Ed. 4, 84 pp., illus. Berkeley and Los Angeles.

(28) Show, S. B.
1924. Some results of experimental forest planting in northern California. Ecology 5:83-94.

(29) Society of American Foresters Committee on Forest Types.
1954. Forest cover types of North America (exclusive of Mexico). 67 pp., illus. Washington, D. C.

(30) Sudworth, George B.
1908. Forest trees of the Pacific Slope. 441 pp., illus. Washington, D. C.

(31) U.S. Department of Agriculture.
1941. Climate and man. Agr. Yearbook 1941. 1,248 pp., illus. Washington, D. C.

(32) U.S. Forest Service.
1908. Bigtree. U.S. Dept. Agr. Silvical Leaflet 19. 5 pp.

(33) _____.
1948. Woody plant seed manual. U.S. Dept. Agr. Misc. Pub. 654. 416 pp., illus.

Schubert, Gilbert H., Rev. by Beetham, N.M.
1962. Silvical characteristics of giant sequoia. U.S.Forest Serv. Pacific SW. Forest and Range Expt. Sta. Tech. Paper 20 rev. 16 pp., illus.

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174.7 Sequoia ~~sempervirens~~ Gigantea:181

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